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CHINA'S YUAN-WANG OCEAN-GOING INSTRUMENTATION SHIPS

Wang Shiying

ABSTRACT

The Yuan-Wang ocean-going ships are an important part of the space TT&C networks in China. They have successfully completed 11 missions in the past 20 years. The tasks of these ships are to track and measure the flight path data of spacecraft and launch rackets, to receive remote information to transmit commands as well as to communicate with and to try to retrieve astronauts during re-entry and splash-down over the sea in the future.

The detailed characteristics of Yuan-Wang's structure, its main components, durability, adaptability, and stability in various environments are given in this paper. The shipboard high precision TT&C equipment items include a type 180 monopulse radar, a type 450-3 remote telemetry system, and a type 718 laser position indicator, whose basic compositions and functions are also given. The technical measures to be taken in support of the TT&C system are discussed here.

Key words: Aerospace tracking instrumentation ship, ocean-going ship, aerospace TT&C system.

China's ocean-going space instrumentation ships are comprehensive instrumentation ships which were constructed in accordance with the requirements of the development of the national space program and China's level of technology. They are the ocean-going mobile instrumentation stations of the space TT&C network. They can be positioned at appropriate locations in the oceans in accordance with the needs of spacecraft and launch rocket orbit and telemetry and control needs. Their missions are to track and measure the spacecraft orbit as directed by the Satellite Control Center, receive telemetry signals, transmit remote commands, and retrieve astronauts splashing down in the ocean.

China's two Yuan-Wang ocean-going instrumentation ships were completed in 1979 and conducted their first mission in 1980. Following this, they satisfactorily completed the mission of conducting tracking and orbit measurement of China's first self-designed experimental communications satellite and the third stage of its launch rocket. In 1986 the two Yuan-Wang instrumentation ships underwent technological modifications, following which their revised instrumentation and communications system technological specifications were evaluated as follows.

Following modifications, the systems had markedly enhanced technical capabilities. The precision of attitude and positioning were improved by a full order of magnitude, achieving automatic buoy positioning. Ship-to-shore communications capacity was tripled. Digital transmission speed was increased sevenfold, reliability, stability, coordination, real-time capabilities, speed and level of automation were all greatly enhanced. It achieved standardization and serialization, improving in-country and international compatibility. Following technical modifications, the Yuan-Wang ships satisfactorily completed five major launch experimental missions. During the launch of the Yazhou-1 communications satellite, the Yuan-Wang

instrumentation ships used data from measurement of the short orbital entry arc to determine preliminary orbital data, meeting customer requirements. The precision of its measurements was comparable to those of the Hughes Corporation land-based monitoring and control stations. The evaluation committee was of the unanimous opinion that following modifications, the overall technological level of the telemetry and communications systems of the Yuan-Wang instrumentation ships achieved the international level of the eighties, laying an excellent technological foundation for launch follow-up missions.

In July, 1990, the Yuan-Wang instrumentation ships once more successfully completed tracking and measurement missions for China's launch of an Australian simulation satellite and a Pakistan satellite at the same time using one of her Changzheng-2E powerful carrier rockets.

The Yuan-Wang ships were primarily constructed for different types of space instrumentation missions. They are also well equipped with ocean navigation, weather, electromechanical, communications, rigging, medical and rescue systems. Below we will introduce the characteristics and capabilities of the vessels, the makeup of the instrumentation and control systems as well as technological measures taken to ensure the completion of the instrumentation and control missions.

Characteristics

[Translator: This paragraph was illegible due to smudged reproduction.]

Total length: 191m
Length of water line (light loading): 176.4m
Model width: 22.6m
Model depth: 12.6m

Draft (light loading); 8.87m
Displacement (light loading): 21,076 tons
Height of fore gunwale: 18.4m
Height of aft gunwale: 15.5m
Highest point of ship above reference line: 36.6m

Capabilities

The Yuan-Wang ships have a continuous cruise range of 18,000nautical miles and are self-sustaining for 100days. Their speed and tow capabilities are as follows.

Main engine rated power is 16,000hp, rated rotational rate is 118rpm, and cruising speed is 20knots. Maximum rotational rate is 122rpm at a speed of 20.7knots. Minimum stable rotational rate is 15rpm, which produces a speed of 2knots. When using the main engine for towing at slow speed ahead, speeds can attain 3knots. There is a 25ton towing column at the stern of the ship which can be used for towing when necessary.

The Yuan-Wang instrumentation ships are highly seaworthy. They can navigate at will at 60^0 N Lat and can also navigate in a Class 4 ice region. Their gale resistance is: wind area $2.543m^2$; fully loaded, the ships can withstand winds of 81.62m/s.

In addition, the Yuan-Wang ships are also fairly strongly resistant to sinking and have good bulkhead rupture stability. If any two connecting bulkheads are ruptured and allow water in, the ship will not sink. Its waterline will remain below the upper deck and initial stability always remains above 1m. This meets the requirements of bulkhead rupture stability.

These ships also have fairly strong directional stability. When under automatic pilot, the coarse can be kept within plus or minus 1^0 and instantaneous deviation will be no greater than 2^0.

When using manual pilot and with a fixed left rudder angle of 2 to 4^0, it can maintain course stability. This ship has mooring turning and positional stability indexes as follows.

At the prow of the ship there is an 800-kW prow positioner and at the aft there is a 340-kW main rudder. These are used for turning and for directional stability when anchored.

When the main drive rudder and the prow directional apparatus are operating independently, in a Class 3 wind (3.4m/s) it can keep the ship at an average angular velocity of 15^0/min around its original position. When working in unison, they can turn the ship around its original position at an angular rate of 24^0/min. In Class 3 seas it can keep the ship at the same direction within a stability of plus or minus 5^0.

Composition and Capabilities of Measurement and Control System

The Yuan-Wang instrumentation are equipped with single-pulse radars, type 195 microwave unified measurement systems, dual-frequency measurement equipment, type 450-3 shipborne telemetry systems, type 718 laser television theodolite, comprehensive ship attitude and positioning systems, reproduction distortion measurement equipment, and a central computer. Their normal operations sequence is ensured by a time-standardized service system and a communications system. The type 180 monopulse radar is one of the major items of equipment for tracking and measuring targets in flight. It operates on the C-band in a single-pulse system. Its parabolic antenna is 9m in diameter. It can track and measure targets through a reflected and answering mode. It has a maximum operational ranges of: $0-360^0$ over water, an angle of elevation of $2-182^0$ (anchored on deck). When using the answering mode to track and measure, it can operate using more than one set of single-pulse radars.

The radar capture and guidance equipment is a continuous-wave signal trace tracking system; it operates on the S-band. The conical sweep is 7.4-8.4^0. The conical sweep frequency is 24cps. The parabolic antenna is 1.5m in diameter. It is hooked up to the side of the single-pulse antenna. The antenna polarization mode is a revolving circle polarization. Its operational ranges are the same as those for the single-pulse antenna.

The type 185 microwave unified instrumentation and control system works together with the phase parameter responder. It can perform multiple station-fixing to measure orbits. When the target is also equipped with phase-parameter and nonphase-parameter responders, it can conduct four-station fixing on the orbit. Whether using the phase-parameter or the nonphase-parameter mode, it always uses a standardized carrier wave for tracking and measurement, remote sensing and remote control functions.

The type 185 microwave unified instrumentation and control system operates on the C-band. The parabolic antenna is 9m in diameter. It can be used for the measurement of earth synchronous orbit satellite positioning, changing orbits, semi-synchronous orbit and synchronous orbit measurement, control and remote-sensing reception, and can also conduct instrumentation, control and remote sensing reception of low-orbit space vehicles equipped with coordination responders or beacon transmitters. The entire system can capture the target for at least 18s with a rated signal to noise ratio with S/Φ/C=40min·Hz. The precision angle tracking ranges are: horizontal angle of 0-360^0, and angle of elevation 3-70^0.

The coding remote sensing modulation mode is PCM/ΔPSK/PM.

The analog remote sensing modulation mode is FSK/PM.

The multiplex carrier wave remote-sensing modulation mode is PACM/MF, PCM/FM or PM.

The remote control modulation mode is PCM/ASK/PM or FM.

It also has a 1.5-m small antenna guidance apparatus used to guide the large antenna to capture the target and in discrimination. The acquisition time is no more than 2s. The guidance success probability is no less than 99%.

The dual-frequency instrumentation equipment can receive two satellite or guidance signal frequency phase-parameter signals and measure their doppler shifts; receive medium speed and high speed variance remote-sensing information and receive meridian instrument satellite time orbit information. The horizontal angle is 0-360^0 and the elevation angle is -5 to 360^0.

The 450-3 shipborne remote-sensing unit includes the C-band microwave remote-sensing and P-band remote-sensing equipment. Operational ranges are: horizontal angle 0-360^0, elevation angle -4 to 77^0. It has digital, analog, and manual guidance capability.

The microwave remote-sensing unit can also perform doppler velocity measurements. The ultra-shortwave remote-sensing unit can guide the microwave remote sensing to acquire the target with reliability.

The type 718 laser television theodolite consists of a television tracking and measurement system, a laser rangefinding system, astronomical locating equipment, stable platform and round top. It can precisely measure orbits and also execute astronomical position-fixing and course-fixing and perform nighttime satellite observation. Its operational ranges are: horizontal angle 0-360^0, and angle of elevation -5 to 185^0.

The type 718 laser television meridian instrument, the type 180 radar, and the type 185 microwave unified instrumentation and control system are all equipped with a low-light television system used for automatic buoy calibration and automatic tracking and instrumentation by the equipment.

The display distortion measurement system consists of two parts: flex distortion measurement and display measurements. It uses the principle of optical collimation and has very high precision. It is used to test the various items of equipment for their angular variance between horizontal, perpendicular and course directions for inertia guidance and inertial guidance frame of reference.

The central computer can collect measurement information from various locations in the external measurement equipment, ship-position and ship-attitude information of the comprehensive guidance system, information from the flex-distortion and display measurement, remote sensing data, in real-time transmit this to the Xian Spacecraft Flight Control Center for real-time processing. At the same time it transmits it to the instrumentation ship command and control center for display and plotting, for quasi-real-time processing of satellite-orbit data or warhead splashdown point data. Depending on requirements, it can also carry out other computational tasks.

The central control room includes monitor display systems, plotting boards, closed-circuit television, and 40 consoles is the command and control center for the entire ship. To ensure coordination of the normal operations of the various items of measurement and control equipment mentioned above, the Yuan-Wang ships use:

1. Time synchronizing service system: This is composed of a rubidium clock, a BMP timer, a signal generator and an amplifier.

It is used to ensure that all the equipment on the ship is synchronized. The timing system on the ship serves to coordinate UTC. The BMP timer receives a shortwave time signal from the China Academy of Sciences Xian Observatory, the PO-21 fully-automatic long-wave timer receives a long-wave time signal from the "Loran C" station or receives a long-wave timing signal from the China Academy of Sciences' Xian Observatory.

2. Communications system: This is composed of a satellite communications ship station, a high-power shortwave, super-long-wave, super-shortwave, shortwave and control system equipment. Its mission is to ensure ship-to-shore and ship-to-ship as well as internal ship command and data communications.

3. Weather system: This is composed of a high-altitude weather radar and satellite cloud-mapping receiving equipment. Its mission is to provide a basis for atmospheric corrections for measurement data and to independently conduct weather forecasting.

Technical Measures to Ensure Instrumentation and Control Operations

1. Ship stability serves to improve the stability of the vessel when taking measurements. In addition to increasing ballast, two roll-reduction fins are added forward on the bottom. The forward fin can be extended to a maximum of 25.94m and the rear fin can be extended to 26.49m. They can keep the rolling and pitching of the ship within the requirements of the instrumentation equipment in Class 6 seas (4.75-m waves).

2. Tracking stability. To ensure relative stability between the optical equipment viewing angle and the tracking wave beam of the radio instrumentation equipment within the inertial-coordinate system, a stability platform is installed separately

on the base of the optical equipment. During target tracking by the radio instrumentation equipment, the ship-roll signals and the radio-rate gyroscope signals are processed and then transmitted to the antenna servo system for real-time correction, achieving stable tracking of the target. The stability platform has a degree of isolation from ship rolling of more than 40dB. The rate gyroscope has an isolation of more than 30dB when doing stability feed forwarding.

3. Display distortion error correction. This uses optical collimation to measure precisely and provide the error between the stabilization platform an the inertial guidance reference platform nd the flex distortion error between the instrumentation-equipment antenna-reference coordinates and the inertial-guidance reference when switching coordinates.

4. Electromagnetic capacitance design: located on the top deck of the ships are 54 antennas of various sizes. In order to overcome electromagnetic interference, during design and layout, a rational selection is made of the operating frequencies and frequency spectra of the electronic equipment; there is a rational layout of the equipment and antennas, and strict antenna selection and cable-laying. Furthermore, shielding, restricting and filtering technology must be used.

5. Measures to overcome adverse environments: the instrumentation ships sail the oceans for long periods of time and will frequently encounter high temperatures, high humidity, waves, and salt fog. For normal and reliable operation and long life of the electronic equipment on board the ship, it is equipped with waterproof portholes and doors. All the cabins are air-conditioned. Electrical devices use large-scale integrated circuits and are sealed and heated. Exposed portions are treated against moisture, salt fog, and mildew.

6. Scheduled testing and calibration: the ship and the various items of mechanical and electronic equipment on board are subjected to regularly scheduled maintenance, measuring and testing to determine the zero point of the various items of equipment. This equipment is subjected to regular static evaluation to determine the amount of error. When on a mission at sea using a low light television tracking system to chart the stars, there is random automatic calibration to ensure the precision of the equipment and the systems.

Since being built, the two Yuan-Wang space instrumentation ships satisfactorily carried out eleven major national missions and seven long-range missions in the South Pacific. They withstood Class 12 winds. These tests have demonstrated that China's space instrumentation ships are of rational structure, the various items of equipment all operate with reliability and high precision. The ships can provide a full range of services. They are two citadels of knowledge on the seas. The Yuan-Wang space instrumentation ships will in the future play an even greater role in China's space endeavors and in her launching services for the international space market.

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